Investigating the Risks of Airborne Particulate Matter Using the National Medicare Cohort

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ABSTRACT

Evidence on the health risks associated with short-term exposure to fine particles (particulate matter less than 2.5 μm in aerodynamic diameter-$PM_{2.5}$) is limited. Results from the new national monitoring network for $PM_{2.5}$ make possible systematic research on health risks at national and regional scales.

Objective: To estimate risks of cardiovascular and respiratory hospital admissions associated with short-term exposure to for Medicare enrollees and to explore heterogeneity of the variation of risks across regions.

Design, Setting, and Participants: We assembled a national database comprising daily time-series data for the period 1999-2002 on hospital admission rates for cardiovascular and respiratory outcomes and injuries, ambient levels, and temperature and dew-point for 204 US urban counties. Daily hospital admission rates were constructed from the Medicare National Claims History Files (NCHF). Our study population included 11.5 million Medicare enrollees living on average 5.9 miles from a monitor.

Main Outcome Measures: Daily counts of county-wide hospital admissions for primary diagnosis of cerebrovascular, peripheral, and ischemic heart diseases, heart rhythm, heart failure, chronic obstructive pulmonary disease, and respiratory infection, and injuries as a control outcome.

Results: We found evidence of short-term increased hospital admission rates associated with $PM_{2.5}$ for all of the health outcomes except injuries. The largest effect was for heart failure: a 1.28% increase in risk per 10 $\mu g/m^3$ increase in same day $PM_{2.5}$ (95% CI 0.78 to 1.78%). We also found that cardiovascular risks tend to be higher in eastern counties.

Conclusion: Short-term exposure to $PM_{2.5}$ increases hospital admission risks for cardiovascular and respiratory diseases. By linking Medicare, pollutant, and weather data, we created a national database for continued research that can be updated and analyzed repeatedly to track the health risks of air pollution.

METHODS

Our study population includes 11.5 million Medicare enrollees residing on average 5.9 miles from a PM2.5 monitor. We restricted the analysis to the 204 US counties with populations larger than 200,000. Of these 204 US counties, 90 have daily data across the study period and the remaining have $PM_{2.5}$ data collected once every three days for at least one full year of the four.

County names and location, air pollution data, weather data, county-specific estimates of health risk, and software developed to construct county-specific time series data are available at (http://www.biostat.jhsph.edu/MCAPS). Billing claims of Medicare enrollees are not publicly available.

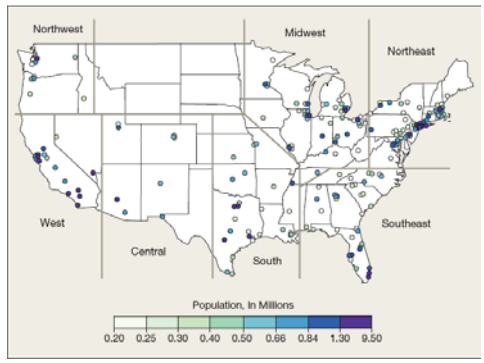
Calculations were implemented using the statistical software R. We applied Bayesian two-stage hierarchical models to estimate county-specific, regional, and national average associations between day-to-day variation of $PM_{2.5}$ at lags 0, 1, and 2 days, and county-level hospital admission rates, accounting for weather, seasonality, and long-term trends.

We also applied distributed lag models to the 90 counties with daily $PM_{2.5}$ data available to estimate the relative rate of hospitalization associated with cumulative exposure over the current day and the two previous days.

At the second stage, to produce a national average estimate of the short-term association between $PM_{2.5}$ and hospital admissions, we used Bayesian hierarchical models to combine relative rates across counties accounting for within-county statistical error and for between-county variability of the "true" relative rates (also called "heterogeneity").

We examined the sensitivity of key findings with respect to lag of exposure; degrees of freedom in the smooth functions of time, temperature and dew point.

Figure 1. US Counties With Populations Larger Than 200 000 Included in Analysis

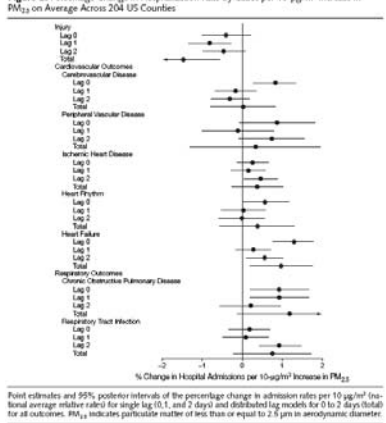


RESULTS

We found evidence of positive associations between day-to-day variation in concentration and hospital admissions for all outcomes, except injuries, for at least one exposure lag (Figure 2). The largest effect was found at lag 0 for all of the cardiovascular outcomes except ischemic heart disease, for which the largest effect was at lag 2. For respiratory outcomes, we found that the largest effects occurred at lags 0 and 1 for COPD and at lag 2 for respiratory infections. Distributed lag estimates were statistically significant for heart failure. The wider posterior intervals for the distributed lag estimates, compared with the single lag estimates, reflect the restriction of the analysis to the 90 of the 204 counties with daily data.

Several analyses were conducted as internal checks on the methodology. We ran all analyses for lag -1, that is, we used the next day's pollution to predict today's outcome, and for hospitalizations caused by injuries and other external causes. As expected if our methods are reasonably unbiased, we did not find positive associations for injuries or for other external causes, or when using lag -1 $PM_{2.5}$ as the exposure indicator. The main results were robust to the number of degrees of freedom used to adjust for temporal confounding, to the adjustment for weather, and to the prior distributions.

Figure 2. Percentage Change in Hospitalization Rate by Cause per 10-μg/m³ Increase in $PM_{2.5}$ on Average Across 204 US Counties

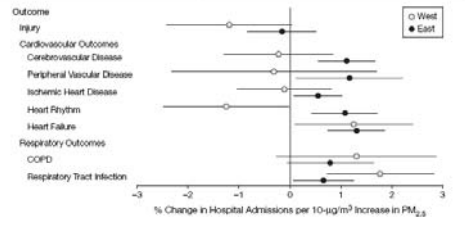


Point estimates and 95% posterior intervals of the percentage change in admission rates per 10 μg/m³ (national average relative rates) for single lag (0, 1, and 2 days) and distributed lag models for 0 to 2 days (total) for all outcomes. $PM_{2.5}$ indicates particulate matter of less than or equal to 2.5 μm in aerodynamic diameter.

We further investigated regional differences by dividing the US into a "US East" region (Northeast, Southeast, Midwest, and South) and "US West" region (West, Central, and Northwest). Using analysis of variance, we found that the East/West differences in risks were statistically significant for all cardiovascular outcomes except for heart failure and for respiratory infections.

Relative rate estimates for cardiovascular outcomes were all positive and statistically significant in the "US East," but not in the "US West" (Figure 4). Relative rate estimates for respiratory infections were larger in the "US West" than in the "US East." We investigated effect modification of short-term effects of on hospital admission rates by both county and regional averages of concentrations, temperature, and ozone. We found that both county and regional average temperature positively modifies the association between and hospital admission rates for the two respiratory outcomes: comparing two regions which differ by 1 degree (F), in the warmer region we estimated 18 and 9 additional admissions per 10,000 people for COPD and respiratory infections, respectively, per 10 increase in . We did not find evidence of effect modification by average concentrations of either or ozone.

Figure 4. Percentage Change in Hospitalization Rate by Cause per 10-μg/m³ Increase in $PM_{2.5}$ for the US Eastern and Western Regions for all Outcomes



Point estimates and 95% posterior intervals of the percentage change in admission rates per 10 μg/m³. $PM_{2.5}$ indicates particulate matter of less than or equal to 2.5 μm in aerodynamic diameter; COPD, chronic obstructive pulmonary disease.

Finally we calculated the yearly hospital admissions attributable to a 10 reduction in the daily $PM_{2.5}$ level (Table 2). For example, for heart failure we estimated that a 10 reduction in $PM_{2.5}$ would reduce the number of hospitalizations by 3,156 for the 204 urban counties

Table 2. Annual Reduction in Admissions Attributable to a 10-μg/m³ Reduction in the Daily $PM_{2.5}$ Level for the 204 Counties in 2002

Cause-Specific Hospital Admissions	Annual No. of Admissions	Annual Reduction in Admissions (95% PI)*
Cerebrovascular disease	226 641	1836 (680 to 2992)
Peripheral vascular disease	70 061	602 (–42 to 1254)
Ischemic heart disease	346 082	1523 (69 to 2976)
Heart rhythm	169 627	967 (–17 to 1951)
Heart failure	246 598	3156 (1923 to 4389)
COPD	108 812	990 (196 to 1785)
Respiratory tract infection	226 620	2085 (929 to 3241)

Abbreviations: COPD, chronic obstructive pulmonary disease; PI, posterior interval; $PM_{2.5}$, particulate matter of less than or equal to 2.5 μm in aerodynamic diameter.
*Per 10-μg/m³ reduction in $PM_{2.5}$.

DISCUSSION

We describe a national approach for using the Medicare NCHF to estimate short-term effects of on cause-specific hospitalization rates. Because the source mix for $PM_{2.5}$ varies across locations, we explored spatial variation of the effect of $PM_{2.5}$ on risk for hospitalization. Because the magnitudes of the effects contrasted greatly in comparing the more eastern regions to the west, we grouped the cities into two regions, eastern and western. There are known differences in the composition of particles and in the mix of sources across these broad areas. Research should shift toward the difficult issue of identifying those characteristics of particles that determine their toxicity . The EPA's Speciation Trends Network, which is now providing extensive data on characteristics of $PM_{2.5}$ at selected sites, offers a needed resource for this research .

Under the Clean Air Act, the Administrator of the EPA is required to set a PM NAAQS that protects public health with an "adequate margin of safety". Our findings indicate an ongoing threat to the health of the elderly from airborne particles and provide a rationale for setting a $PM_{2.5}$ NAAQS that is as protective of their health as possible.